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ADVANCED SPECTRUM ANALYZER.(U)
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ADVANCED SPECTRUM ANALYZER

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ADVANCED SPECTRUM ANALYZER OPTICAL SYSTEM DESIGN

1.0 INTRODUCTION

This is the third bimonthly technical progress report on the Advanced Integrated Optical RF Spectrum Analyzer (IO RF SA) Program, Phase I. The objective of this phase of the program is the extension of the operational capability of the IOSA to (1) a useful linear dynamic range of 40 dB, beginning at a signal-to-noise ratio (SNR) of 6.7 dB, for RF input pulses with durations of 0.4 μsec or longer and (2) a differential signal strength sensitivity of 40 dB for simultaneous long-duration pulsed or CW RF signals separated in frequency by 16 MHz. A second phase of the program, which is contingent upon the success of the first phase, will be directed toward increasing the RF center frequency from 600 MHz to at least 1 GHz, extending the instantaneous RF bandwidth from 400 MHz to a value between 500 and 700 MHz (specification to be decided upon at the inception of Phase II), and producing several prototype IOSA assemblies for delivery to NRL.

Efforts during this reporting period covered all major developmental areas of the program with the exception of geodesic lens fabrication and testing. Emphasis was placed upon (1) investigations of the applicability of GaAlAs diode lasers from three different manufacturers to the optical system of the advanced IOSA; (2) continued efforts toward butt-coupling of General Optronics lasers mounted on our heat sinks to $LiNbO_3$:Ti waveguides; and (3) exploration of techniques to improve the

performance of the 5050 photodiode array and its associated readout electronics in order to decrease to system noise level toward the basic noise level of the photosensor chip. Progress in each of these areas will be summarized in the sections which follow, and the program plan for the next bimonthly period is outlined in the final section.

2.0 LASER DIODES FOR IOSA OPTICAL SYSTEM

The focal length of the input, or collimating, lens in the optical system of the advanced IOSA was left unspecified in the previous bimonthly reports because insufficient information was available on expected waist sizes of the General Optronics lasers being developed for the IOSA. It was noted, however, that a waist of 2.5 - 3 μm would be desirable in order to avoid the fabrication of low F/number collimating lenses because the fabrication tolerances on short focal length geodesic waveguide lenses are significantly tighter than those for longer focal lengths. In addition, the short focal length lenses will also require larger curvatures in their surface contour which will result in reduced through-put efficiency. As a result, an effort is being made to examine laser diodes from various suppliers in an effort to identify a source with a minimum beam divergence. Laser diodes from General Optronics were measured together with some Hitachi Series 1400 diodes which we purchased for this purpose. All were found to exhibit beam divergences which ranged from 16^{o} to 25^{o} and some were found to exhibit more than one transverse mode. We also were given some ITT laser diodes to

evaluate for the spectrum analyzer application. This was done, and the devices were found to be either multimode or to exhibit a considerable amount of structure in the far field pattern in addition to having beam divergences in excess of 25°.

3.0 LASER BUTT-COUPLING

It was mentioned in the second bimonthly report that we successfully coupled one of the General Optronics lasers into one of our waveguides. This was accomplished using a special mounting fixture designed for this purpose. This fixture requires that the height of the active region of the laser be determined prior to mounting the laser on the waveguide. This measurement is accomplished using Lloyd's fringes formed off the specular surface of the copper heat sink. Once this measurement has been made, two screws are adjusted using an electronic dial gauge so that they protrude from the top surface of the heat sink by the precise amount required to place the active height of the laser at a point 0.8 μm above the air-waveguide interface when the waveguide is placed face-down in the CERVIT mounting fixture. These screws can be set to an accuracy of approximately 0.1 μm. Two additional screws are also utilized in the mounting fixture to set the distance between the laser's front facet and the waveguide edge. These are adjusted under a microscope to protrude approximately 1 μm beyond the front facet of the laser, and they are placed in contact with the polished edge of the $LiNbO_3$ substrate.

Some difficulty has been encountered in measuring the height of the active region on some of the General Optronics

lasers. This difficulty has resulted from the fact that the heat sink surface is not always intact after the bonding step has been completed at General Optronics. In one instance, indium, used as the bonding material, was found beyond the face of the front facet, while in another instance deep scratches on the surface prevented the observation of a measurable fringe pattern. In instances where the heat sink surface is not damaged and none of the indium solder protrudes from the front facet, this measurement can be made accurately to approximately 1 μm. In order to optimize the coupling efficiency it will probably be required that this height adjustment be dithered around the initial setting since the measurement of the height of the active region cannot be made to the 0.1 μm accuracy felt to be necessary to yield optimum coupling.

We have been successful in butt-coupling a General Optronics laser, then removing it and subsequently coupling it again. Unfortunately the beam divergence of this laser was sufficiently great to place a significant amount of radiation upon uncorrected regions of our F/8 collimating lens. In addition, the laser output from this diode was observed to diminish with time. It was found that the indium bond to the copper heat sink had failed providing a very poor thermal contact. Subsequent efforts to rebond this laser to the heat sink resulted in its destruction.

4.0 DETECTOR READOUT CIRCUITRY

Another phase of the program involves efforts to improve upon the noise characteristics of the Westinghouse 5050 detector array and output circuitry. The maximum output signal from the 5050 detector is limited to approximately 1.5 volts. Therefore,

in order to achieve a dynamic range for RF input power at 50 dB, signals on the order of 15 μV must be handled at the output of the detector. Additionally, the analog signal pulses from each of the 10 channels are output at a 5 MHz rate. Unfortunately, the noise levels of the commercially available Multiplexers, Sample and Holds, and A/D converters which operate at such frequencies are on the order of 100 μV.

By multiplying the output of the detector by a factor of 10, the noise added by these output components will not appreciably degrade its dynamic range. Thus, a wideband, low noise, large signal, linear gain of ten amplifier is needed. Operational amplifiers using feedback will satisfy all these conditions except the extreme low noise specifications.

Specifically, an input noise voltage which is less than 15 μV 84 percent of the time (over a 5 MHz bandwidth) corresponds to an input Johnson thermal noise of 2.4 nV r.m.s./$\sqrt{Hz}$. The input noise of the amplifier should be significantly less than this. Commercial wideband modular op-amps with input noise as low as 4 or 5 nV r.m.s./$\sqrt{Hz}$ are available. Not only do these amplifiers not meet the lowest noise specifications, but they are large and expensive. Since one amplifier is needed for each of 10 channels, a less extravagant amplifier design in terms of cost and space is being developed which will meet the noise requirements.

The design utilizes a moderately low noise wideband op-amp (input noise $\cong$ 7 - 10 nV r.m.s./$\sqrt{Hz}$) and a low noise J-Fet (input noise $\cong$ 1.2 nV r.m.s./$\sqrt{Hz}$). The direct approach of designing a

low noise discrete component differential input stage for the op-amp will reduce its effective input noise component by the gain factor of the discrete input stage. To reduce the number of noise components to a minimum, a variation on this approach produced the circuit in Figure 1. This is a gain of six amplifier using an LH0032 op-amp and 2N4392 J-Fet. Theoretically, the noise for a gain of 10 amplifier should be as low as 1.6 nV r.m.s./$\sqrt{Hz}$. Graphical analysis of single sweep oscilloscope pictures of the noise have verified noise under 2 nV r.m.s./$\sqrt{Hz}$ for the gain of six amplifier.

The picture in Figure 2 shows the output of the gain of 6 amplifier after going through a bandpass filter (1 kHz to 1 MHz). The picture in Figure 3 shows the input to the same gain of 5 amplifier, using the same bandpass filter. Note, all of the noise in this picture is due to the input noise of the oscilloscope, not the input noise of the amplifier. Figure 4 shows the large signal operation of this amplifier using the same bandpass filter.

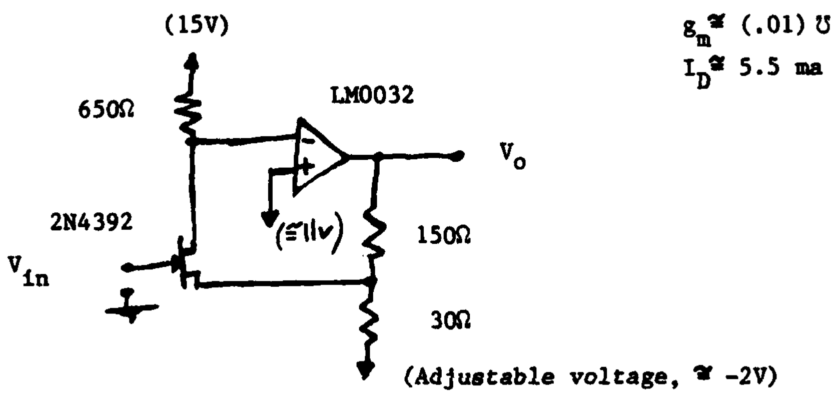

Fig. 1 - Gain of Six, Wideband, Low Noise, Large Signal Amplifier

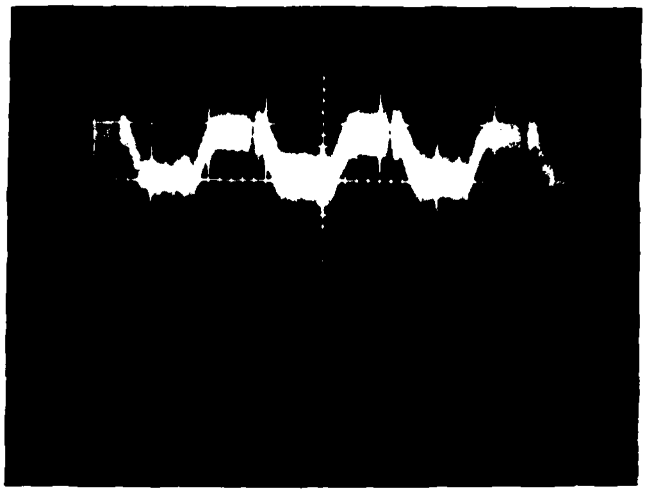

Fig. 2 - 50 μV/div 1 μs/div

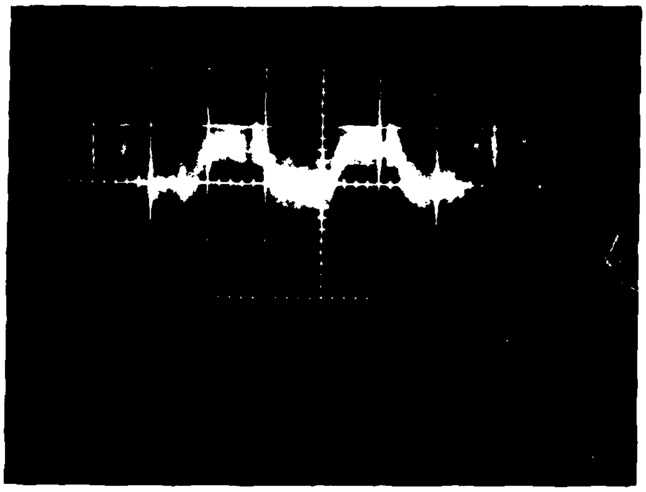

Fig. 3 - 10 μV/div 1 μs/div

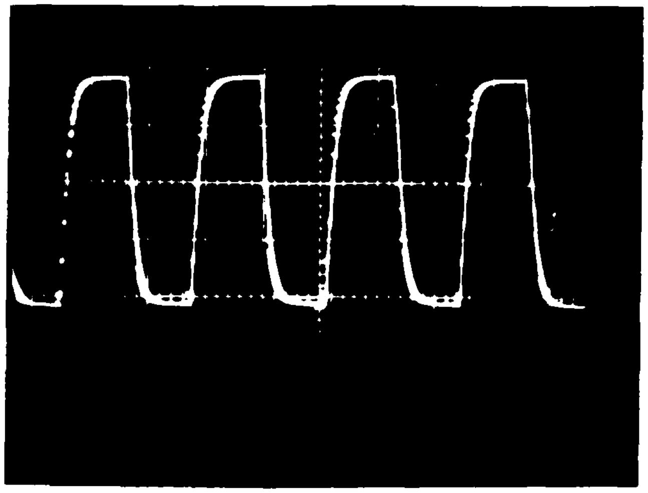

Fig. 4 - 1 V/div 1 μs/div

5.0 PROGRAM FOR NEXT BIMONTHLY REPORT PERIOD

During the next bimonthly period we will continue to work on the butt-coupling problem with some laser diodes we expect to receive from Hitachi. They have agreed to provide us with unbonded, untested chips so that we must develop a suitable bonding technique to place them on our heat sinks before proceeding with height and beam divergence measurements. We will also continue with the improvements to the detector readout circuitry and will make our first attempt to fabricate geodesic lenses on a different machine at Pneumo Precision Inc. in Keene, New Hampshire.

The spending on the program through this report period has provided a total expenditure of \$87.5K of the first phase allocation of \$205K.

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